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Fatal injuries among motorcyclists in Klang Valley, Malaysia

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ABSTRACT

Background: Motorcycle fatalities constitute the majority of road traffic deaths in Malaysia. The aims of this study were to describe the pattern of fatal injuries among Klang Valley fatal motorcyclists and to describe the factors associated with fatal (*vs* non-fatal) injuries.
Methods: A cross-sectional analysis was performed on data from a case series of injured (fatal and non-fatal) motorcyclists recruited from Klang Valley between 14th March 2010 and 13th March 2011. Fatal cases in the cases series were identified from the Police files. Non-fatal cases were recruited from five major hospitals in the study region. Information used in the analyses were obtained from Police crash reports, hospital medical records, and Coroner's records of the participant sample.
Results: Of the 177 fatal cases, 142 (80.2%) were categorised as instantaneous death while 35 (19.8%) cases were categorised as experiencing delayed death. Thirty two percent of the cases had a Maximum Abbreviated Injury Score (MAIS) of 5 with head injury being the most common cause of death. Significant predictors of fatal (*vs* non-fatal) injury included ethnic groups, monthly income, alcohol and drug use and road type. Alcohol and drug use was shown to be the strongest predictor with adjusted odds ratio (AOR) of 14.77 (95% CI 3.32–65.65).
Conclusion: Factors related to the motorcyclists, road user behaviour and the road environment as well as pre-hospitalisation emergency care must be addressed efficiently in low and middle income countries to reduce the number and severity of motorcycle-related injuries.

1. Introduction

By 2030, road traffic crashes (RTC) will be the fifth leading cause of the world's deaths.[1] In the Western Pacific region alone, approximately 800 people die on the roads every day with millions more suffering serious injuries. Malaysia has the highest RTC death rate among the Association of the South East Asian Nations (ASEAN) countries.[2] In Malaysia, in 2010, there were 6260 fatalities, 6002 serious injuries (requiring hospitalisation) and 10,408 moderate injuries.[3] With a total population of more than 28 million this equates to a rate of 23.03 deaths per 100,000 population, and a rate of 3.43 per 10,000 registered vehicle,[4,5] substantially higher rates than many other countries.

Motorcyclists account for a high proportion of deaths and serious injuries, with motorcyclist fatalities being three times higher compared to passenger car fatalities, six times higher than pedestrian fatalities and nearly 50 times higher than bus passenger fatalities.[6] The Malaysian Institute of Road Safety Research (MIROS) reported that prior to 1992 the number of motorcycle fatalities was lower than that of other vehicle user fatalities, however, during the mid-1990s (particularly from 1993 to 1996) the number of motorcycles in the vehicle fleet increased greatly, with an associated steep increment in the number of motorcycle fatalities: an increment of 22% from 1993 to 1994, 12% from 1994 to 1995 and 14% from 1995 to 1996.[7]

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Given the high trauma associated with motorcycle-related crashes, any effort to reduce the number and severity of these crashes is a high priority for Malaysia. However, in order to develop and implement the most effective interventions to reduce the burden of motorcycle crash deaths in low and middle income countries, a better understanding of the nature of the fatal injuries and of the factors associated with fatal (*vs* non-fatal) injuries is required. While the international research has established a number of risk factors for motorcycle crashes in highly motorized countries, less is known about the risk factors in low and middle income countries. The aims of this study, therefore, were to describe the pattern of injuries amongst fatally injured motorcyclists in Klang Valley, Malaysia, and to identify those factors associated with fatal (*vs* non-fatal) outcomes.

2. Methods

A cross sectional analysis was performed on a population-based case series of motorcycle users (riders and pillions) who were injured in road crashes in Klang Valley, Malaysia. This study received the approvals from Monash University Human Research Ethics Committee (MUHREC), Ministry of Health of Malaysia (MOH), all selected hospitals and Police departments where the samples were selected.

2.1. Study period

Data collection was conducted over a 12-month period, from 14th March 2010 to 13th March 2011.

2.2. Study population

The study population comprised all individuals who sustained injuries or had been killed as a motorcycle rider or pillion during the study period.

A fatal case was defined as a motorcycle rider or pillion who was involved in a motorcycle crash and sustained severe injury to any part of the body that resulted in instantaneous death or death within 30 days following the crash.[8,9] Fatal cases in the case series were identified from the Police files and traced at the five selected hospitals.

A non-fatal case, was defined as motorcycle rider or pillion who presented to the emergency department of the selected hospitals in Klang Valley and treated as an outpatient or admitted as an inpatient.

The inclusion criteria comprised all ethnic groups, gender and age groups with all forms of injuries that could be classified using the Abbreviated Injury Scale (AIS).[10] Cases with a diagnosis that could not be classified using the AIS, or who sustained their injury in a road crash that occurred outside Klang Valley area and participants (non-fatal) who did not wish to participate in this study, were excluded.

2.3. Procedures and variables examined

Three data sources were used for data collection: i) Police crash reports, ii) hospital medical records, and iii) Coroner's records.

The records of a crash maintained by regional Police Departments included a range of information comprising: demographic details and crash characteristic variables including collision vehicles, site details and collision type (available in descriptions as well as photographs). Helmet information however, was not maintained by the Police as this was not categorised as mandatory information.

The records maintained by the Coroner included medical reports prepared by the forensic pathologists, providing clinical description of injuries and cause of death, and toxicology and chemical analysis of the blood, urine or other body fluid (analyses undertaken by the Chemistry Department).

Hospital-based data was collected from analysis of medical records and included patient demographic characteristics, clinical description of injuries and results of investigations.

Using these three data sources, a set of variables were created for analysis and addressed the following: i) rider and pillion socio-demographic details (age, gender, ethnic group and monthly income); ii) road characteristics (road characteristics and road configuration); iii) crash characteristics (riding position, alcohol and illicit drug intake, type of colliding partner, type of collision and posted speed); iv) helmet characteristics (helmet type and helmet fixation categorised as fixed, dislodged, when the helmet came off upon impact and unknown fixation); and, v) injury characteristics (type of injury according to body site and severity of injury categorised by the AIS and Maximum Abbreviated Injury Scale (MAIS)).

2.4. Statistical analyses

The data were analysed quantitatively using the Predictive Analytics SoftWare (PASW: formerly SPSS) statistics version 18.0 (SPSS Inc., Chicago, IL). Descriptive data are shown as frequencies and percentages. The associations between the variables and the mortality outcome were initially explored using the chi-square test. Following this test, in order to assess the relationship between the predictors to the mortality outcome, a multivariate analysis, in the form of binary logistic regression was performed.[11] The method used was backward elimination. All independent variables which showed $p < 0.25$ in the univariate associations were entered into multivariate analysis for further investigation. Other independent variables which were considered to be clinically important although not statistically significant were also entered into the multivariate analyses.[12] Interaction terms were constructed for each covariate pair and tested for significance. Interaction is confirmed if it is statistically significant in the regression model.[13] The overall model fit was assessed by Hosmer–Lemeshow goodness-of-fit test.

We included 'unknown' or 'no information' in the analysis based on the nature of this research which involved fatal cases or non-fatal cases but with head injury who were incapable of remembering the event.[14] The unknown status is a common finding in real life situation involving motorcycle-related injuries and this had been reported by various authors.[14–17] 'Unable to remember event' or 'no answer could be obtained' did not happen randomly and omitting it will produce a biased result.[14]

3. Results

Of the 755 participant recruited, there were 177 fatal and 578 non-fatal cases. The characteristics of the fatal and non-fatal cases are shown in Table 4.

3.1. Injury characteristics

A full three-cavity autopsy was conducted in two hospitals while the forensic pathologists at the other three hospitals, performed three-cavity autopsy as well as partial autopsy.

The principal cause of death was head injury (45.2%) while thoracic and abdominal injuries were sustained by 10.7% and 5.6% of the fatal and non-fatal cases respectively. Head and thoracic

injuries were the two most predominant injuries in the group who sustained multiple injuries.

Ten (5.6%) motorcyclists died due to complications related to underlying medical conditions or co-morbidity and, of these, 60% were due to ischaemic heart disease, 20% with severe lung infection, immune-deficient state due to chemotherapy (one case) and a hospital-acquired sepsis (one case) (Table 1).

3.1.1. Type of injuries according to the most common MAIS

Overall, the most common type of injury in each body region and severity of injury is shown in Table 2.

The Injury Severity Score (ISS) ranged from 4 to 75 with mean (standard deviation, SD) of 41.3 (20.5). MAIS 5 was the most common severity among all head injuries, with intracerebral haemorrhage and subdural haemorrhage documented as the most frequent traumatic brain injury. Soft tissue and facial fractures, especially fractures of the maxilla and mandible, were the most common types of facial injuries.

The most common neck injury was the MAIS 2 cervical spine fracture in the form of body or spinous process fracture. Apart from cervical spine fractures, a third of MAIS 2 injuries were hyoid bone fractures. In relation to most common thoracic and abdominal injuries, thoracic MAIS 3 were associated with multiple rib fractures, lung contusion and haemothorax while the three most common abdominal organs involved in the MAIS 2 injuries were the kidneys, liver and intestines. Finally, injuries to the extremities were the most frequent injuries encountered among all the injuries, as were facial injuries. The most common severity examined was MAIS 2 upper extremities fractures followed by the lower extremities fractures.

3.1.2. MAIS 4, 5 and 6 injuries in all fatal cases

Of the total number of fatal cases, 142 (80.2%) cases were categorised as instantaneous death (death at the scene and before arrival to hospital) while 35 (19.8%) cases were grouped into death that occurred between the time period from within a few minutes after arrival at the Emergency Department to 30 days of hospitalisation.

Table 3 shows severe (MAIS 4), critical (MAIS 5) and untreatable (MAIS 6) forms of injuries among the fatal cases.[10] Of these injuries, head injuries showed the highest involvement with 51.7%, followed by thoracic injuries with 23.5% and abdominal injuries with 19.7%.

Of all the severe (MAIS 6) head injuries, the majority were crush injuries involving the skull, brain and intracranial content (25 cases: 75.8%), brainstem laceration (4 cases: 12.1%), brainstem transection (2 cases: 6.1%) and midbrain laceration (2 cases: 6.1%). All four cases of severe (MAIS 6) neck injuries comprised complete transection of the spinal cord. For the thorax, the severe (MAIS 6) injuries comprised multiple laceration wounds of the heart (one case), ventricular rupture (two cases), complete transection of the descending aorta (two cases) and a crushed chest. Regarding severe abdominal injuries, the three cases of MAIS 6 were hepatic avulsion (two cases) and a case of torso transection.

Table 1
Cause of death in the fatal subjects.

Cause of death (according to site)	Fatal subjects ($n = 177$)	
	n	%
Head	80	45.2
Neck	5	2.8
Thorax	19	10.7
Abdomen	10	5.6
Multiple sites	53	29.9
Underlying co-morbidity	10	5.6

Table 2
Most common types of injuries among fatal motorcyclists in Klang Valley.

The most common injuries and severity according to body region
Total number death = 177

Body region	MAIS	Most common type of injury	n	%
Head	5	Intracerebral haemorrhage, Subdural haemorrhage	57	32.2
Face	1	Soft tissue injuries and facial fractures	90	50.8
Neck	2	Cervical spine fracture Hyoid bone fractures	16	9.0
Thorax	3	Multiple ribs fracture, lung contusion and haemothorax	56	31.6
Abdomen	2	Organ injuries, i.e. kidney, liver, intestine	27	15.3
Extremities	2	Soft tissue injuries and upper and lower extremities fractures	90	50.8

3.2. Study factors characteristics

Thirteen variables were extracted to examine their contribution to crash involvement and the descriptive results for these factors are shown in Table 4. In terms of socio-demographic characteristics, the majority of fatally injured motorcyclists were Malay males, especially aged between 16 and 25 years. 'Others' in the ethnic grouping were East Malaysians as well as immigrants from countries such as Indonesia, Myanmar, Pakistan, Bangladesh and Palestine. The majority of deaths (92.1%) involved riders. Nearly half earned less than three thousand Ringgit Malaysia (approximately USD1000) per month. All fatally injured motorcyclists underwent toxicology screening which involved investigation of presence of alcohol and drugs (medicinal or illegal) in blood, urine and other body fluid. Just under one-quarter (23.2%) of the cases tested positive for alcohol or illicit drugs or both, while 32.2% were confirmed to be alcohol or drug free, but tested positive for prescription drugs. A substantial proportion (44.6%) of the results were not finalised. Further examination of this variable revealed that, among the 41 cases with positive alcohol and drug use, 58.5% had ethyl alcohol, 31.7% were confirmed with illicit drugs and 9.8% with a combination of ethyl alcohol and illicit drugs. The highest blood alcohol concentration (BAC) level documented was 390 mg/100 ml while the lowest was 0.02 mg/100 ml (mean 182.7 mg/100 ml, SD 87.9). In relation to the illicit drugs, presence of a single drug was slightly more common than presence of multiple drugs (5.6% *vs* 4.5%). The illicit drugs included ketamine, amphetamine, methamphetamine,

Table 3
MAIS 4, 5 and 6 injuries in relation to all deaths.

MAIS 4, 5 and 6 injuries involving all body regions
Total number death = 177
Total number of MAIS 4,5 and 6 injuries = 213

Body region	MAIS	n	%
Head	4	20	9.4
	5	57	26.8
	6	33	15.5
Neck	5	3	1.4
	6	4	1.9
Chest	4	20	9.4
	5	24	11.3
	6	6	2.8
Abdomen	4	19	8.9
	5	20	9.4
	6	3	1.4
Extremities	5	2	0.9
Face	4	2	0.9
Total		213	100

Table 4
Socio-demographic, road, crash and helmet characteristics of non-fatal and fatal motorcyclists in Klang Valley.

	Non-fatal cases ($n = 578$)		Fatal cases ($n = 177$)		Univariate analysis	
	n	%	n	%	Odds ratio (95% CI)	*p*-Value
Gender						
Female	61	10.6	12	6.8	Reference	
Male	517	89.4	165	93.2	1.62 (0.85–3.09)	0.14
Ethnic group						
Malay	396	68.5	72	40.7	Reference	
Chinese	70	12.1	27	15.3	2.12 (1.27–3.53)	0.004
Indian	80	13.8	55	31.1	3.78 (2.47–5.79)	<0.001
Others	32	5.5	23	13.0	3.95 (2.19–7.14)	<0.001
Age group						
<16	33	5.7	8	4.5	Reference	
16–25	264	45.7	82	46.3	1.28 (0.57–2.88)	0.55
26–35	133	23.0	36	20.3	1.11 (0.48–2.63)	0.80
36–55	127	22.0	36	20.3	1.17 (0.50–2.75)	0.72
56–80	21	3.6	15	8.5	2.95 (1.07–8.15)	0.04
Riding position						
Pillion	69	11.9	14	7.9	Reference	
Rider	509	88.1	163	92.1	0.63 (0.35–1.16)	0.14
Monthly income						
No income/ fixed income	160	27.7	39	22.0	Reference	
≤3 k	356	61.6	76	42.9	0.88 (0.57–1.35)	0.54
>3 k	31	5.4	7	4.0	0.93 (0.30–2.26)	0.87
No information	31	5.4	55	31.1	7.28 (4.15–12.77)	<0.001
Alcohol and illegal substance use						
No	494	85.5	57	32.2	Reference	
Yes	44	7.6	41	23.2	8.08 (4.87–13.40)	<0.001
No information	40	6.9	79	44.6	17.12 (10.71–27.36)	<0.001
Road type						
Intracity	166	28.7	52	29.4	Reference	
Highway	114	19.7	59	33.3	1.65 (1.06–2.57)	0.03
Federal road	83	14.4	35	19.8	1.35 (0.81–2.23)	0.25
Residential road	151	26.1	19	10.7	0.40 (0.23–0.71)	0.00
Rural road	41	7.1	8	4.5	0.62 (0.28–1.41)	0.26
Others	23	4.0	4	2.3	0.56 (0.18–1.68)	0.30
Road configuration						
Straight	274	47.4	112	63.3	Reference	
Intersection	178	30.8	35	19.8	0.48 (0.32–0.74)	0.001
Bends	98	17.0	23	13.0	0.57 (0.35–0.95)	0.03
Others	28	4.8	7	4.0	0.61 (0.26–1.44)	0.26
Colliding partner						
Single vehicle crash	179	31.0	57	32.2	Reference	
Two-wheel vehicles	46	8.0	9	5.1	0.61 (0.28–1.33)	0.22
Four-wheel vehicles	319	55.2	79	44.6	0.77 (0.53–1.15)	0.20
Large vehicles	15	2.6	22	12.4	4.61 (2.24–9.47)	<0.001
Unknown	19	3.3	10	5.6	1.65 (0.73–3.76)	0.23
Type of collision						
Single vehicle crash	179	31.0	57	32.2	Reference	
Frontal	168	29.1	67	37.9	1.25 (0.83–1.89)	0.28
Rear-end	42	7.3	9	5.1	0.67 (0.31–1.47)	0.32
Side	145	25.1	24	13.6	0.52 (0.31–0.88)	0.02
Others	44	7.6	20	11.3	1.43 (0.78–2.62)	0.25
Posted speed (km/hr)						
≤50	77	13.3	9	5.1	Reference	
>50	499	86.3	166	93.8	2.85 (1.40–5.80)	0.00
Unknown	2	0.3	2	1.1	8.56 (1.07–68.35)	0.04
Helmet type						
Half-head/ open-face	480	83.0	117	66.1	Reference	
Tropical	31	5.4	8	4.5	1.06 (0.47–2.36)	0.89
Full-face	18	3.1	0	0.0	–	–
Not wearing a helmet	43	7.4	5	2.8	0.48 (0.19–1.23)	0.13
Unknown	6	1.0	47	26.6	32.14 (13.42–76.97)	<0.001
Helmet fixation						
Fixed on head	315	54.5	67	37.9	Reference	
Dislodged	104	18.0	63	35.6	2.85 (1.89–4.29)	<0.001
Not wearing a helmet	43	7.4	5	2.8	0.55 (0.21–1.43)	0.22
Unknown	116	20.1	42	23.7	1.70 (1.10–2.65)	0.002

methadone, tramadol, morphine, codeine, triprolidine, lidocaine, chlorpheniramine, buclizine, dextromethorphan, alprazolam and cannabis.

Most of the fatal crashes occurred on a highway (33.3%) or an intracity road (29.4%). In addition, a high proportion (63.3%) occurred on straight roads, while 19.8% occurred at intersections and 13.0% on bends. Collision with a four-wheel vehicle, i.e. a passenger car (44.6%) and single vehicle crash (skid, collision with objects or pedestrians) (32.2%) were the two most common type of collision and frontal collisions (37.9%) were the most predominant collision type that resulted in death. Nearly all collisions occurred on roads with a posted speed of more than 50 km/h.

More than half of the fatally injured motorcyclists used the half-head and open-face helmets (66.1%) and another 4.5% wore tropical helmets. Only 2.8% did not wear a helmet. However, there was no helmet information for 26.6% of the cases. Regarding helmet fixation, 37.9% of the fatally injured motorcyclists were still wearing their helmets post-crash and 35.6% had their helmets dislodged. There was no helmet fixation information for 23.7% of the cases.

3.2.1. Predictors of death

Logistic regression modelling was employed to identify predictors of a fatal injury outcome and the final model with adjusted odds ratios is shown in Table 5.

Study factors in the final model included ethnic group, monthly income, alcohol and illegal substance use and road type. The interaction was shown to be statistically significant between ethnic group and alcohol and illegal substance use; monthly income and posted speed; road type and helmet fixation; road configuration and posted speed and colliding partner and type of collision. The Hosmer–Lemeshow goodness-of-fit test was $p > 0.05$ indicating that the model was fit.

4. Discussion

The rate of motorcycle-related deaths has increased over the last few decades in Malaysia and became the number one cause of all road deaths in 1993. Today, motorcyclist deaths are a major road safety concern, comprising 60% of all road user fatalities in Malaysia. This study was different from other studies performed in this country as it described the cause of death based on the clinical diagnoses and severity and it predicts death among motorcyclists in Klang Valley Malaysia. The severity of the injury implies that either the crash mechanism is very severe or the protective role of a helmet [Malaysian motorcyclists has high helmet wearing rate[2]] is limited or both combined together. Klang Valley is located in the Central Region of Peninsular Malaysia and it is the focus of all forms of socio-economic activities. Its rapid development in industrialisation has attracted migration of people from other regions in Malaysia as well as from other Asian countries. Motorcycle is regarded as the most convenient transport by many, Malaysians

Table 5
Multivariate analysis of predictors of death.

Characteristics	Multivariate analysis*	
	Adjusted OR (95% CI)	*p*-Value
Ethnic group		
Malay	1.00	
Chinese	4.20 (1.64–10.73)	0.003
Indians	1.16 (0.54–4.54)	0.416
Others	5.15 (1.44–18.42)	0.012
Monthly income (Ringgit Malaysia)		
No income/fixed income	1.00	
≤3 k	0.45 (0.06–3.18)	0.421
>3 k	–	–
No information	0.02 (0.00–2.11)	0.099
Alcohol and illegal substance use		
No	1.00	
Yes	14.77 (3.32–65.65)	<0.001
No information	16.15 (6.19–42.15)	<0.001
Road type		
Intracity	1.00	
Highway	1.32 (0.48–3.61)	
Federal road	3.20 (1.11–9.27)	0.595
Residential road	0.26 (0.05–1.55)	0.032
Rural road	0.97 (0.12–8.06)	0.140
Unknown	–	0.978

Interaction was shown to be statistically significant in the following covariates and they were included in the final model: ethnic group*alcohol illegal substance use; monthly income*posted speed; road type*helmet fixation; road configuration*posted speed; colliding partner*type of collision.

and non-Malaysians and not surprisingly the number of registered motorcycles was 9,368,454 in 2010.[3] Based from our observation in this study, there were many riders, matured and under-age, who did not have legal riding license (14.7%) and many used motorcycles that were registered to others. Malaysia has its own Road Transport Law as well as Safety Helmet Law (1973) but to date, the number of death among motorcyclists had been shown to be nothing below than 20 people per 100,000 population for many years, making it one of the highest in the South-East Asia Region.

The first objective of this study was to describe the pattern of injuries, in relation to frequency and severity in fatal motorcycle collision. A previous publication from this country showed that, in 186 fatal motorcycle cases studied, 32.8% involved severe injury to more than one organ. Following data stratification, the main causes of death were head injuries, chest injuries, neck injuries and abdominal injuries.[18] The findings of the current study showed that head injuries predominated in all categories, both as single cause of death and in multiple injuries group. This finding is accordance with many studies in other parts of the world.[19–25] The most common severity of head injury in this study was MAIS 5, in the form of intracranial haematoma. Similar to the current findings, Kasantikul and colleagues (2003) showed the following pattern of severe head and neck injuries sustained in fatal collisions in Thailand: lacerated cerebrum, subarachnoid haemorrhage, small subdural haemorrhage, haemorrhage in carotid sheath, complex basilar fracture, large cerebral contusion and prolonged unconsciousness and spinal cord rupture above C3. They showed that 38% of the fatally-injured motorcyclists were wearing a helmet prior to the crash event and among these helmeted group, helmets were only retained in 32% of cases which is in accordance with our findings. In another study, Ankarath et al. (2002) reported that intracranial haemorrhage, cerebral contusion and skull fractures were three most frequently encountered head injuries in all hospital admissions in Yorkshire, United Kingdom.

High speed collision is common in motorcycle crashes and this often result in unsurvivable injuries like transection of upper cervical cord, skull fracture with brainstem laceration or massive crush, fracture/dislocation at atlanto-occipital joint with brainstem laceration or massive crush and complete decapitation, transection of aorta, rupture of left ventricle and massive liver destruction.[26]

Our study showed a significant number of crush injuries which involved the head (25 cases), chest (one case: same victim with concomitant crushed head) and a torso transection. Crush injuries resulting from massive speed collision were shown in this study and in some, the helmets were crushed together with the heads. Most of these injuries occurred on a highway (50%) where the motorcyclists shared their lane with large vehicles. The mechanism involved here is a two-stage collisions, the first one is frequently a simple sideswipe with another vehicle or a single vehicle crash. The fatal component is second collision, with an oncoming vehicle which could not stop within milliseconds to avoid the already fallen victim.

The majority of neck injuries in this study were related to cervical fractures with the most severe form involving transection of the spinal cord. Another significant injury was the hyoid bone fractures, despite other evidence suggesting that hyoid bone fractures in motorcyclists are rare.[27,28] While the mechanism of injury cannot be confirmed from the available information, it is possible that this injury is related to a loose strap. In the event that a helmet slips backwards during a collision, the strap could severely traumatise the anterior neck.[27] Another possible mechanism of the helmet slipping backwards may be because of inappropriate helmet size (i.e., a large helmet worn compared with head size). Observations of a non-fatal injury group of crash-involved motorcyclists showed that the majority of cases wore size 60 helmets (60 cm head circumference) while the head circumferences (median) for males and females were 57.0 cm and 54.8 cm.[29]

Thoraco-abdominal injuries were the next most common fatal injuries and this finding was in accordance with the literature.[19,25,30] Among the thoracic injury group, rib fractures (especially bilateral fractures) were the most common. Rib injuries were shown to be an important indicator of internal organ injuries and highly associated with lung contusion and haemothorax.[19,30] Concomitant fatal injuries within the thoracic region, i.e. injury to the myocardium and thoracic aorta is not uncommon.[19] Our study was in agreement with this finding. In the abdomen, the kidney injuries were the most common form of injuries, however, liver injuries comprised more serious and fatal injuries, i.e. with MAIS 5 and 6 severities.

The findings in the autopsy report in certain areas may be inadequately reported, for example in facial injuries. The absence or under-representation of more serious fractures of the facial bones, i.e. the Le Fort and naso-orbito-ethmoidal fractures was due to inaccuracy in the diagnostic technique as a result of the lack of availability of modern imaging technique such as the computed tomography (CT) during this study period. Diagnoses of facial fractures were made based on clinical examination alone.

The second aim of this study was to better understand the contributing factors to crash and injury risk amongst fatally injured motorcyclists in Malaysia. A comprehensive list of risk factors comprising human, vehicle and environmental factors in pre, during and post motorcycle crash circumstances was compiled by Lin and Kraus in a systematic review.[31] The review revealed that young age, gender (male), low socio-economic status, being inexperienced, past crash experience, no driving license, traffic violation history, high-risk taking behaviour, alcohol and other drug use, motorcycle ownership, excessive and slow speeds and rider's inconspicuity were the contributory factors for risk of motorcycle-related injuries. Lin and Kraus (2009) also noted that the helmet, motorcycle, time, season, rural area and other factors contributed to collision and injury risk.

Our results are consistent with the above findings except that some information was unavailable due to the nature of the sample, i.e. fatal motorcyclists and no interview was carried out with the crash witnesses and family members due to medico-legal reason.

The findings of this study showed that significant predictors of motorcycle mortality were ethnic group (Chinese and other ethnic groups), alcohol and illicit drugs consumption and road types (federal roads). The strongest predictor among all was alcohol and illicit drugs use. Alcohol is a well-known risk factor for crash involvement.[31–35] Examination of Police reports revealed that 49% of motorcycle crash deaths in the US were related to alcohol intoxication compared to 26% of other vehicle crash deaths.[36] Alcohol was shown to contribute to the majority of single-vehicle crashes compared to multiple-vehicle.[37,38] The alcohol related single vehicle crash was more likely to occur at night in run-off-road and loss of control crashes.[39]

Although alcohol is regarded as a well-known risk factor for motorcycle fatalities elsewhere, but that is not the situation in Malaysia. The consumption of alcohol is a very sensitive issue in this country due to religious and cultural beliefs. Although the Muslims are forbidden from taking alcoholic beverages, previous literature showed that the presence of alcohol amongst Malays as well as with other ethnic groups who were involved in RTC was at significant levels.[40,41] In addition, there is evidence that alcohol consumption is prevalent among other ethnic groups like the Chinese, Indians and aborigines.[42,43] In this study, alcohol consumption prior to the collision was recorded for 4.9% of Malay riders, 4.9% Chinese riders, 41.5% Indians and 17.1% from other ethnic groups. The legal BAC limit for fully licensed and novice drivers/riders in Malaysia is 0.08 g/dl, which is above the limit recommended by the WHO.[44,45] Our findings showed that among the fatal motorcyclists tested positive for alcohol, 78.6% were found to have the level above 0.08%. Besides alcohol, another disturbing causative factor is illegal drugs use. The drug abuse situation in Malaysia remains on the rise and this country is also known as the regional hub for methamphetamine production.[46] One of the national issues involving illegal drugs is associated with young motorcycle riders who are known by the locals as *mat rempit* (daredevil riders). *Mat rempit* are mostly Malay males with lower socio-economic background mostly in the age group of 16–25 years old and they report that leisure, boredom, and lack of recreational activity contributed to their involvement in street racing.[47] They often travel in large groups, race on public roads and exhibit extreme and high risk riding behaviours by performing daring motorcycle stunts endangering other road users.[48] Apart from high risk riding actions, *mat rempit* also exhibit other risky behaviour such as smoking, alcohol drinking and recreational drug use.[48] A self-report study revealed that 35.7% of *mat rempits* (893 of 2500 subjects) admitted of consuming alcohol and 44.9% (1123 of 2500 subjects) used illicit drugs such as the opioids, cannabis, amphetamine-type stimulants (ATS) and others.[49] The total number of *mat rempit* in this study was not assessed as many participants refused to reveal the details.

A study conducted by the Malaysian Institute of Road Safety Research (MIROS) showed that among a sample of 391 drivers, riders and pedestrians who died between 2006 and 2009, motorcycle riders comprised 33.8% (the second highest after four-wheel vehicles' drivers) of the total sample for being positive for alcohol or substance use. Of the 33.8%, 22.1% were positive for alcohol only, 9.7% for drugs only while 2.0% for both alcohol and drugs. This research also highlighted the types of drugs taken by some Malaysian road users prior to crash involvement which were the opiates, amphetamines, cannabis, ketamine, benzodiazepines, antihistamines and anti-epileptics. Our findings showed similar alcohol and drug use which is also in agreement with other studies.[50–52]

The road type was one of the significant predictors of a fatal motorcycle collision where crashes occurring on the federal roads showed three times the odds (AOR 3.20, 95% CI 1.11–9.27) compared to the intracity roads. The federal roads just like the highways have maximum speed limit of 110 km/h on certain routes compared to all roads. The federal roads were also shown to have 15.0% of road defects compared to all roads (intracity roads had the highest defects with 38.3% and residential roads with 25.0%). The defects were in the form of potholes or uneven surface and slippery surface due to water, oil and sands. Riding even with normal speed on defective roads could predispose a rider to a collision.

Other significant predictor shown was the ethnic group (Chinese and other ethnicity). Monthly income, although not a significant predictor but worth noting here, reflects the level of education, socio-economic background and maturity as many were secondary school students (12.7% among all participants). Those who had an income of $\leq$RM 3000 had less odds [AOR 0.45 (95% CI 0.06–3.18)] to die than those without an income.

4.1. Limitations

The main limitation of this research was missing data especially on helmet characteristics, which has also been highlighted in many other studies.[14–17,53] This was already discussed in the Methods section. Delay in fatal report completion was another limitation in this study. This involved the autopsy as well as toxicology components. Cases with delayed or incomplete autopsy reports particularly were omitted from the study and this contributed significantly to the reduction of the sample size.

5. Conclusions

Since the 1990s, motorcycle crashes had become the major cause of death especially among young people in this country. Factors such as age, riding position, alcohol and illegal substance use and road types were shown to be significant predictors of death. Injury prevention strategies targeting these factors to change human behaviour through behavioural modification programmes, education and law enforcement must be performed promptly if significant reduction in death and serious injury is to be achieved in the next five to ten years. Speed management especially on highways and federal roads must be concurrently addressed. In addition, given the pattern of serious injuries, pre-hospitalisation emergency care must be enhanced and medical personnel appropriately trained to manage these situations.

The implications of these findings are substantial and can be used to guide the development of strategies and initiatives to reduce motorcycle crashes in Malaysia. Moreover, the findings of this study could be extrapolated to other countries especially within the South East Asia region which have similar road safety issues.

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Conflict of interest
The authors declare no conflicts of interest.

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